

UINTA BASIN VOC COMPOSITION STUDY IMPACTS ON THE 2017 OIL AND GAS EMISSIONS INVENTORY

November 2020 - White Paper – Uinta Basin Air Agencies (Utah Division of Air Quality (UDAQ), EPA Region 8, Ute Indian Tribe)

1 Introduction and Background

The 2017 Uinta Basin Emission Inventory (UBEI2017) was built with input from operators, gap-filling line items, and the EPA-Nonpoint Source Methods Advisory Group's Oil and Gas Tool. In April 2018 operators submitted detailed workbooks reflecting 2017 activity levels, while gap-filling line items were estimated by the Uinta Basin Air Agencies. These data were checked for consistency and anomalies, and verified with operators. The final inventory was presented to industry on August 22, 2019, and reflected version V1.81 of the inventory database. These data were submitted as part of the 2017 National Emission Inventory requirements by the UDAQ and also submitted to EPA to meet the Clean Air Act requirements for a marginal ozone nonattainment area. Since that time, findings from research and requested information have provided an opportunity to update the UBEI2017 to create a more accurate inventory referred to as Updated Uinta Basin Emission Inventory (UBEI2017-Update). UBEI2017-Update will be the basis for Uinta Basin photochemical modeling demonstrations, and accurate speciation of emissions – particularly ozone precursors – crucial to effective ozone mitigation planning. This paper describes the effects on the UBEI2017 from applying findings in the Uinta Basin Composition Study¹.

1.1 Uinta Basin Composition Study

The Uinta Basin Composition Study (UBCS) was a collaborative research campaign supported by the Uinta Basin Air Agencies. The [Uinta Basin Composition Study final report](#) was released in March, 2020. The study results include four speciation profiles describing the chemical composition (C1 to C10+) of raw and flash gas emissions from oil and gas wells and are shown in Table 1. Raw gas (aka field gas) was sampled from the separator gas discharge and pressurized liquids samples were collected from the separator to analyze and estimate flash gas from tanks. These profiles include composition from the sampling of 50 oil wells and 17 gas wells in the Uinta Basin from November 2018 to February 2019. The profiles come from a robust and recent dataset. The dataset has advantages compared to operator-submitted composition reports, which cover a wide range of sampling dates (some are quite old), operating conditions, representativeness, sampling and analytical techniques, and contracted laboratories. These advantages include larger sample size, uniform sampling and analytical methods, as well as a uniform sampling facility and analyst, and there having been collected in a narrow time window compared with the operator submitted reports.

The Uinta Basin Air Agencies Oil and Gas Emissions Inventory (referred to as the Uinta Basin Emissions Inventory, or UBEI) relies on composition profiles in order to calculate emissions rates from various oil and gas equipment types. The UBEI2017 relied on UDAQ-created default raw gas and flash gas profiles by amalgamating all operator-submitted composition reports from the previous inventory year (2014).

¹ Uinta Basin Composition Study Final Report Webpage <https://deq.utah.gov/air-quality/composition-of-volatile-organic-compound-emissions-from-oil-and-gas-wells-in-the-uinta-basin>

Species (WEIGHT PERCENT)	UBCS Raw Gas: Gas Wells	UBCS Raw Gas: Oil Wells	UBEI 2017 Raw Gas	UBCS Flash Gas: Gas Wells	UBCS Flash Gas: Oil Wells	UBEI 2017 Flash Gas
METHANE	73.08	52.36	70.33	46.02	13.72	15.48
ETHANE	10.29	11.41	9.34	18.62	10.39	8.64
PROPANE	5.98	9.57	7.86	16.41	15.92	12.84
ISOBUTANE	1.70	2.24	-	4.72	4.74	-
N-BUTANE	2.17	5.05	5.19	6.11	12.09	12.35
ISOPENTANE	1.02	2.44	-	2.35	5.94	-
N-PENTANE	0.85	3.29	3.11	1.71	7.93	8.25
CYCLOPENTANE	0.05	0.26	-	0.09	0.63	-
N-HEXANE	0.48	2.30	2.48	0.77	6.60	16.64
CYCLOHEXANE	0.27	0.61	-	0.36	1.67	-
HEPTANES	1.54	5.34	0.46	1.23	11.60	6.70
METHYLCYCLOHEXANE	0.67	0.84	-	0.60	2.03	-
2,2,4 TRIMETHYLPENTANE	0.00	0.00	-	0.01	0.05	-
BENZENE	0.08	0.18	0.04	0.11	0.40	0.87
TOLUENE	0.25	0.29	0.05	0.25	0.56	0.77
ETHYLBENZENE	0.02	0.03	-	0.01	0.05	0.07
XYLENES	0.16	0.23	0.05	0.15	0.36	0.37
OCTANES	0.71	1.88	0.29	0.20	2.00	3.13
NONANES	0.15	0.38	0.13	0.26	2.87	2.09
DECANES+	0.52	1.33	0.66	0.03	0.46	11.80
total	100.00	100.00	100.00	100.00	100.00	100.00
average VOC Wt %	14.80	32.54	20.33	35.65	72.41	75.88
average MWwhole gas	19.39	24.17	20.10	-	-	-
average VOC/CH4 ratio	0.210	0.699	0.29	1.14	19.91	-

Table 1: Raw gas (blue) and flash gas (green) speciation profiles from the Uinta Basin Composition Study (UBCS) and the original UBEI2017. The UBCS created separate profiles for oil wells and gas wells, while oil and gas profiles were combined in the UBEI2017.

The oil and gas emissions inventory incorporates speciation data into VOC emissions rate calculations for the following equipment types:

- Pneumatic controllers (raw gas)
- Pneumatic pumps (raw gas)
- Fugitives (raw gas)
- Storage tanks (flash gas)
 - Capture Effectiveness of Tanks (flash gas)
- Well Liquids Unloading (flash gas)
- Equipment and Piping Blowdowns (raw gas)

This white paper describes the methods by which the UBCS speciation profiles were applied to the UBEI2017. To maintain the spatial resolution of the inventory, adjustments were applied at a facility level when possible. Table 8 summarizes VOC emissions for UBEI2017 and UBEI2017-Update at the end of this white paper.

1.2 Preparation of UBEI2017 Data for Analysis

The UBCS included samples from upstream oil or gas production facilities in the Uinta Basin, so the adjustments discussed in this analysis were only applied to production facilities located in Uintah & Duchesne counties in the UBEI2017. Results from the UBCS showed significant distinctions between oil and gas well emission composition, so the application of these profiles to the UBEI2017 requires separation between oil- and gas-producing facilities. Delineations between oil- and gas-producing facilities were made according to the “Production Type” column in the Fugitives tab of the 2017 UBEI operator workbook. Production facilities with the Production Type “gas” or “shale gas” are considered gas production facilities; facilities of type “oil” or “waxy crude” are considered oil production facilities. The UBEI2017 default flash gas and raw gas composition profiles provided in the operator workbooks did not distinguish between oil and gas production.

UBEI2017 had some updates since August of 2019 when the emission inventory was first presented to industry (V1.81). One operator revised their original submission by adjusting annual operating hours for their equipment (RICE and Turbines, Separators and Heaters, Pneumatic Controllers, Pneumatic Pumps, Fugitives). Another operator inadvertently missed reporting for 106 production facilities handling production from 174 oil wells acquired on 1/1/2018. The UBEI2017 captures 2017 activities and operators had until April of 2018 to report their inventory. It was verified that no other operator reported on these facilities. An updated workbook for the missing facilities was supplied and added to the inventory database. This update had a significant impact on the uncontrolled emission estimates for tanks with controls (of the 106 additional facilities, 105 were reported with controlled tanks and 1 without tank controls). The effect of these updates to UBEI2017 oil and gas emissions inventory is tabulated below.

UBEI2017 Database Updates (Excludes Gap Filling)							
	em_pm10	em_pm25	em_sox	em_nox	em_voc	em_co	em_ch2o
Starting Emissions (V1.81)	458	458	26	11,370	54,579	11,014	555
Updated Emissions (V1.85)	446	446	25	10,662	55,596	10,107	546

UBEI2017 Tanks Inventory			
	UBEI2017 (V1.85)	UBEI2017 V1.85 Additions	Additions % of Total
Number of Controlled Facilities with Tanks	1,266	105	8.3%
Number of Uncontrolled Facilities with Tanks	6,259	1	0.0%
Controlled Tank Emissions VOC (tons/yr)	1,004	689	68.6%
Uncontrolled Tank Emissions VOC (tons/yr)	8,406	4	0.0%

Tables 2 & 3: (2) Total criteria pollutant emissions in Uinta & Duchesne counties from updates to database versions. (3) Number of facilities with tanks onsite and VOC emissions from those tanks.

1.3 Description of Statistical Tests Used in These Analyses

Before applying the UBCS speciation profiles to the UBEI2017, a statistical test was evaluated in order to answer the question “Are the UBCS profile data statistically significantly different from the profile data used by operators in the UBEI2017?” The null hypothesis is that UBCS profile data, such as VOC weight

percent, whole gas molecular weight, or methane-to-VOC ratio, is no different than the set of analogous operator-submitted and default profile data. If the null hypothesis is correct, then there is no reason to apply the UBCS profiles to the UBEI because the data sets are not statistically significantly different.

2-sample permutation tests were run on the data to test for difference in the mean values between VOC weight percent data from the UBCS and UBEI2017 for flash gas and raw gas respectively. For flash gas: with a resulting p value of $0.017 \leq 0.05$ we reject the null hypothesis that there is no difference between means. For raw gas: with a resulting p value of $2.2e-16 \leq 0.05$ we reject the null hypothesis that there is no difference between means. The difference in datasets are therefore statistically significant for VOC weight percent as well as other descriptions of these two datasets, including whole gas molecular weight, methane-to-VOC ratio, and tank emission factors, as all of these factors are derived from (or correlated with) the VOC weight percent.

The UBCS endeavored to be representative across 7 of the largest operators in the Uinta Basin. Production volumes and samples were collected and analyzed in a methodologically consistent manner. All UBCS samples were collected and analyzed between November 2018 and February 2019. Operator-submitted composition data have unquantified uncertainty in the representativeness of the samples and in the method used for sample collection and analysis, with noted divergence in methodology for flash gas composition analysis. Some operator-supplied data were collected and analyzed more than 10 years ago. Due to the statistical and methodological differences between these datasets, it is reasonable to replace all values that relied on default or operator-provided composition data in the UBEI2017. In 2017, 27 operators provided their own composition data, while 37 operators used UDAQ-provided default composition. Operator-provided composition data were applied to 8,581 facilities, while the remaining 1,460 facilities relied on the 2017 UBEI default composition profiles.

2 Pneumatic Controllers

Emissions from pneumatic controllers are estimated using emission factors from EPA. The document [“Oil and Natural Gas Sector: Standards of Performance for Crude Oil and Natural Gas Production, Transmission, and Distribution. Background Technical Support Document for Proposed Standards \(EPA-453/R-11-002, July 2011\)”](#) describes the following methodology:

“The basic approach used for this analysis was to first approximate methane emissions from the average pneumatic device type in each industry segment and then estimate VOC and hazardous air pollutants (HAP) using a [representative gas composition](#). The specific ratios from the gas composition were 0.278 pounds VOC per pound methane ... in the production and processing segments...”

The “representative gas composition” included in the emission factor calculation was not sourced from Utah, but rather calculated as an average of gas composition from several production areas across the U.S. The VOC weight % cited for pneumatic controller calculations from this existing EPA documentation was 3.66%. The UBCS speciation profiles have average raw gas VOC weight percentages of 15% for gas and 33% for oil production facilities. These values are more representative of Uinta Basin raw gas composition—which describes the composition of the gas used to power pneumatic controllers. For this reason, the VOC-to-methane ratio assumed in EPA’s pneumatic controllers’ calculation is superseded by the UBCS ratio, as shown in the equation below.

$$UBEI2017Update\ VOC\ (TPY) = UBEI2017\ VOC\ (TPY) \times \frac{1\ lb\ CH_4}{0.278\ lb\ VOC} \times \left[UBCS\ \frac{VOC}{CH_4} \right]$$

VOC-to-methane weight percent ratio data come from raw gas composition from production facilities sampled in the UBCS. The sum of VOC weight percentages (C3-C10+) were divided by the methane weight percent (C1) for each sample. The ratios were then separated by production facility type (either oil or gas) and then averaged within each production facility type to calculate a representative VOC-to-methane ratio. The figure below shows the UBCS ratios from oil and gas production facilities and the existing EPA ratio.

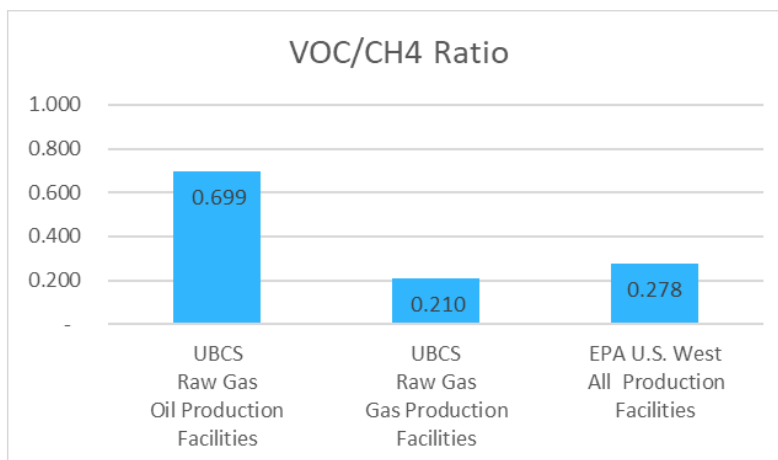


FIGURE 1: COMPARISON OF VOC-TO-CH4 RATIOS FROM THE UBCS (LEFT BARS) AND EPA DATA (RIGHT BAR).

Pneumatic controllers in the emissions inventory were divided into controllers associated with gas production facilities (to which the 0.207 Gas VOC-CH4 ratio was applied) and controllers associated with oil production facilities (to which the 0.699 Oil VOC-CH4 ratio was applied). Because the VOC-CH4 ratio for gas production facilities is slightly lower than the existing EPA ratio, total VOCs from pneumatic controllers associated with gas production facilities decreased. Total VOCs from pneumatic controllers associated with oil production facilities increased significantly, resulting in a net increase in total VOCs from all pneumatic controllers in UBEI2017-Update.

2.1 Results

The UBEI2017-Update total pneumatic controller VOC emissions are estimated at 5,474 TPY VOC. This is an increase of 1,593 TPY from UBEI2017 (+2,160 TPY from Oil production facilities and -567 from Gas production facilities).

3 Fugitives

Fugitive emissions are estimated according to the total number of components per facility and the service line to which those components belong. This analysis adjusts total VOCs from fugitive emissions by replacing the VOC weight percent for components “in gas service” and does not adjust components in light oil, heavy oil, or water/oil service. The calculation below describes fugitive VOC emissions estimation for the “in gas service” service line.

$$Fugitives\ VOC\ (TPY) = (Gas\ Service\ VOC\ wt\ \%) \times \frac{hours \times \sum(\#of\ components \times component\ emission\ factor)}{2000}$$

Fugitive VOCs were adjusted by replacing the “in gas service” VOC weight percent with the UBCS raw gas VOC weight percent at each oil or gas production facility according to the equation below.

$$UBEI2017Update\ Fugitives\ VOC\ (TPY) = UBEI2017\ Fugitives\ VOC\ (TPY) \times \left[\frac{UBCS\ VOC\ Wt\ \%}{Gas\ Service\ VOC\ Wt\ \%} \right]$$

The default “in gas service” VOC weight percent in UBEI2017 was 25%, which is greater than the VOC weight percent from gas production facilities and less than the VOC weight percent from oil production facilities. Not all operators used the default 25% VOC weight percent; operator-submitted VOC weight percentages ranged from 0.06% to 60.42%. The average VOC weight percent for all facilities, including those which used the default VOC weight percent (25%), is shown below.

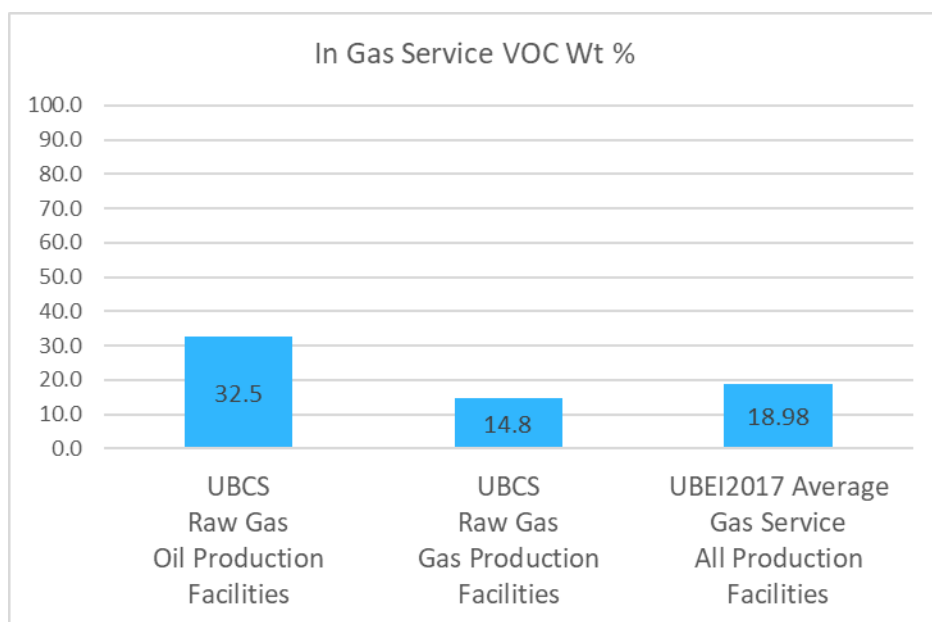


FIGURE 2: COMPARISON OF VOC WEIGHT PERCENT OF RAW GAS FROM THE UBCS (LEFT BARS) AND THE AVERAGE UBEI2017 VOC WEIGHT PERCENT USED FOR IN GAS SERVICE FUGITIVE COMPONENTS (RIGHT BAR).

3.1 Results

The UBEI2017-Update total fugitive VOC emissions is estimated as 18,248 TPY VOC. This is an increase of 497 TPY from UBEI2017 (+128 TPY from Oil and +369 from Gas).

4 Pneumatic Pumps

Emissions from pneumatic pumps are estimated according to the equation below. Whole gas molecular weight and VOC weight percent of raw gas emitted from pneumatic pumps are either default values

from the UBEI2017 or supplied by operators.

Pneumatic Pumps VOC (TPY)

$$= \left[\text{Average Vent Rate} \left(\frac{\text{scf}}{\text{hr}} \right) \right] \times \frac{60 \text{ min}}{379 \frac{\text{scf}}{\text{lbmole}}} \\ \times \left[\text{Whole Gas Molecular Weight} \frac{\text{lb}}{\text{lbmole}} \right] \times [\text{Annual hours}] \\ \times [\text{VOC weight fraction}] \times \frac{1 \text{ ton}}{2000 \text{ lbs}} \times [1 - \text{Control}\%]$$

Raw gas whole gas molecular weight and VOC weight percent are compared in the figures below, showing that both raw gas data types are higher at oil and at gas facilities than the UBEI2017 average molecular weight and VOC weight percent for all production facilities. Not all operators used the UBEI2017 default whole gas molecular weight (20.1 lb/lb-mol) or the default VOC weight percent (20.3%). The UBCS molecular weight and VOC weight percent for raw gas at oil and gas facilities is compared to the UBEI2017 default values below.

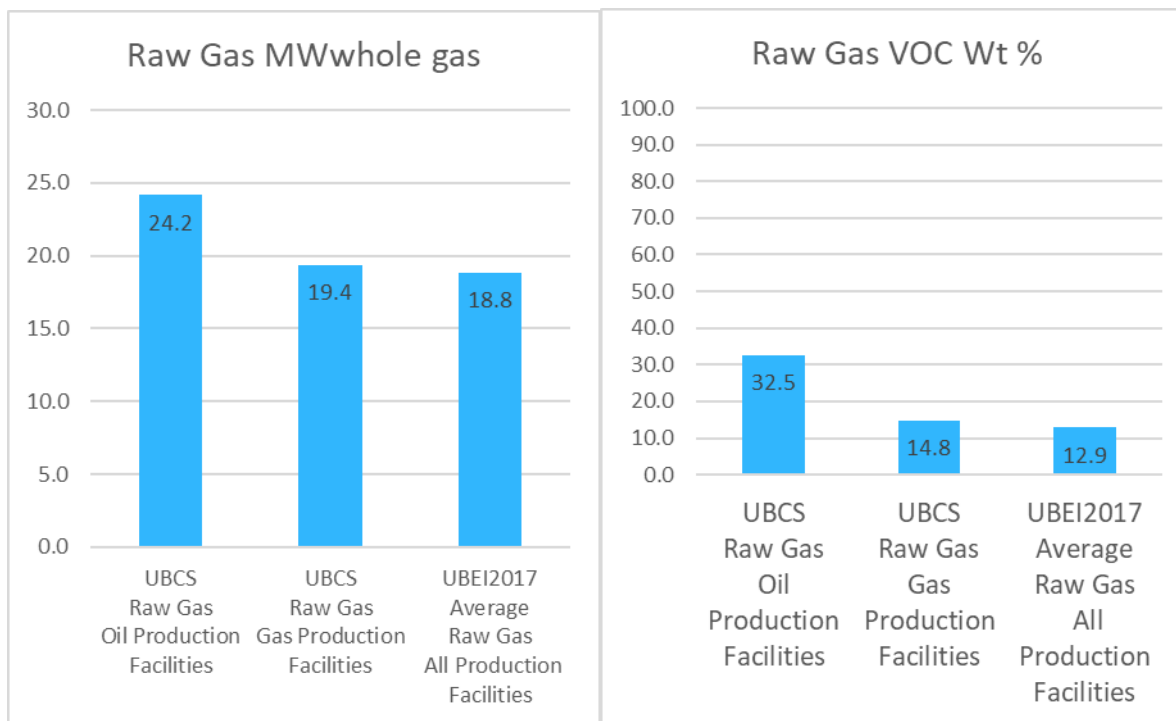


FIGURE 3: COMPARISON OF RAW GAS MOLECULAR WEIGHT OF THE WHOLE GAS AND COMPARISON OF VOC WEIGHT PERCENT OF RAW GAS BOTH USED IN ESTIMATING VOC EMISSIONS FROM PNEUMATIC PUMPS. IN EACH GRAPH, THE LEFT BARS REFLECT THE UBCS VALUES AND THE RIGHT BARS REFLECT AVERAGE VALUES USED IN THE UBEI2017.

These results are applied to each oil or gas production facility's pneumatic pumps by replacing the whole gas molecular weight and VOC weight percent in the equation above and recalculating the total VOC emissions. The majority of pneumatic pumps are at gas production facilities.

4.1 Results

The UBEI2017-Update total pneumatic pumps VOC emissions are estimated at 11,590 TPY VOC. This is an increase of 2,856 TPY from UBEI2017 (+235 TPY from Oil production facilities and +2,621 TPY from Gas production facilities).

5 Storage Tanks

5.1 UBCS Tank Emission Factor Calculations in ProMax

ProMax software was employed to estimate tank emissions using the extended C1-C36+ pressurized liquid sample analyses collected at 50 oil and 17 gas production facilities in the UBCS. ProMax is a process simulation model that employs an equation of state (PSM/EOS) in order to estimate emissions from oil and gas equipment. More information about ProMax model simulations for Uinta Basin tanks can be found in the [UBCS Final Report](#). This analysis leveraged ProMax's Tank Losses calculation block, which calculates flash emissions from the Peng-Robinson equation and SWB emissions from AP-42 calculations.

Inputs to ProMax:

- pressurized liquid composition (C1-C36+, CO₂, N₂, O₂) for both oil and condensate tanks as weight percentages
- Separator pressure and temperature
- Tank pressure and temperature (tank gauge temperature for heated oil tanks, otherwise ambient temperature at the time of sampling)
- Annual oil or condensate throughput in barrels/year for each production facility according to UDOGM. Data ranged from mid-2018 to mid-2019 in order to align with UBCS sampling time frame.
- Set Bulk Temperature to Stream Temperature = TRUE*
- Tank size, paint condition, insulation (fully insulated for oil tanks and uninsulated for condensate tanks), geographic location (all tanks were calculated to be approximately near Roosevelt, UT), roof type and slope

**This is a setting in ProMax that more closely approximates the actual temperature of liquids moving from a separator to a tank.*

These ProMax simulations resulted in a total tank emission factor (flashing and SWB emissions) in pounds of VOC per barrel of oil produced (VOC lb/bbl) for each production facility sampled in the UBCS. 67 emission factors were calculated in total, 17 of which were gas production facilities and 50 were oil production facilities. The following two subsections compare these ProMax simulation results from the UBCS to UBEI2017.

5.2 A Note About Tank Emission Factors Reported in UBEI2017

Operators had an option within the UBEI2017 workbook to either provide separately calculated flash and standing/working/breathing (SWB) emission factors, or to provide a single combined flash & SWB emission factor. For the purposes of this analysis, any flash and SWB emission factors were added together so that all combined tank emission factors could be considered.

For the 50 oil production facilities which were sampled in the UBCS, the UBCS-based tank emission factor (calculated in ProMax as described above, shown in navy in the figure below) is compared to the operator-submitted tank emission factor for those same production facilities in the UBEI2017 (shown in pink). Most operators used an averaged tank emission factor applied to multiple tanks, so the navy and pink dotted lines represent the average tank emission factor across all 50 oil tanks for UBCS and UBEI2017 respectively. The UBCS average emission factor is nearly 2 times greater than the average UBEI emission factor for the same production facilities.

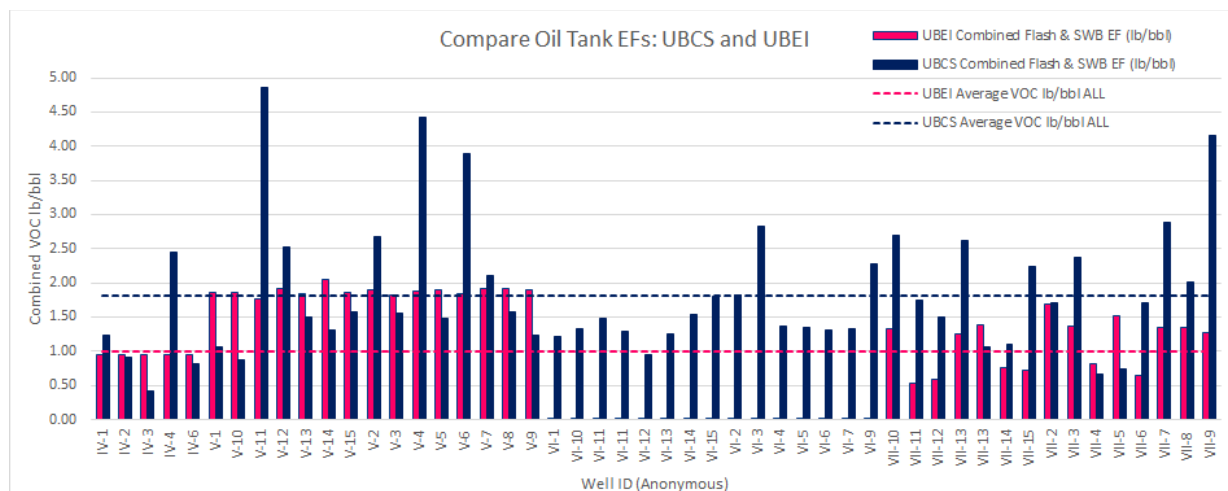


FIGURE 4: COMPARISON OF TOTAL EMISSION (FLASH AND SWB) FACTORS FROM THE UBCS (NAVY) AND UBEI2017 (PINK) FOR 50 OIL PRODUCTION FACILITIES IN THE UINTA BASIN (THE UBEI2017 LB/BBL FOR FACILITIES VI-1 THROUGH VI-9 WAS 0.02 LB/BBL).

For the 17 gas production facilities which were sampled in the UBCS, the UBCS-based tank emission factor (calculated in ProMax as described above, shown in navy in the figure below) is compared to the operator-submitted tank emission factor for those same production facilities in the UBEI2017 (shown in pink). The UBCS average emission factor is again nearly 2 times greater than the average UBEI2017 emission factor for the same production facilities.

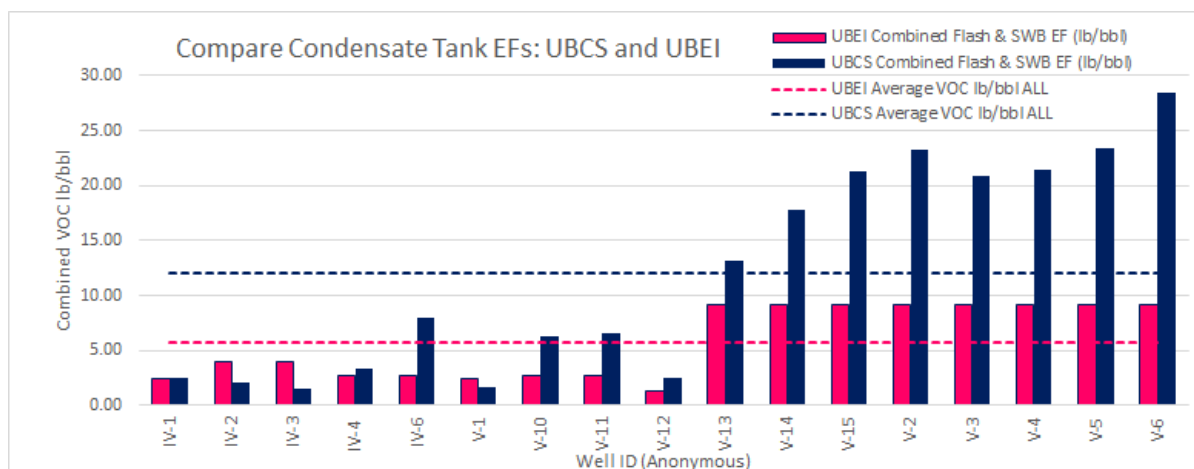


FIGURE 4: COMPARISON OF TOTAL EMISSION (FLASH AND SWB) FACTORS FROM THE UBCS (NAVY) AND UBEI2017 (PINK) FOR 17 GAS PRODUCTION FACILITIES (CONDENSATE TANK EQUIPPED) IN THE UINTA BASIN.

5.3 UBEI2017-Update Emissions from Tanks

Emissions from tanks in UBEI2017-Update were calculated by estimating the emissions resulting from the difference between the average UBCS and the facility-specific operator-submitted tank emission factors. The following two equations were applied to every oil and condensate tank in UBEI2017, respectively.

$$\begin{aligned} & \text{UBEI2017Update VOCs from Tanks (TPY)} \\ &= \text{UBEI2017 tank emissions} \\ &+ \left[\frac{(1 - \text{Control \%})}{2000} \times (\text{Average UBCS oil tank EF} - \text{UBEI2017 oil tank EF}) \times \text{Tank Throughput} \right] \end{aligned}$$

$$\begin{aligned} & \text{UBEI2017Update VOCs from Tanks (TPY)} \\ &= \text{UBEI2017 tank emissions} \\ &+ \left[\frac{(1 - \text{Control \%})}{2000} \times (\text{Average UBCS condensate tank EF} - \text{UBEI2017 condensate tank EF}) \times \text{Tank Throughput} \right] \end{aligned}$$

5.4 Results

The UBEI2017-Update total storage tank VOC emissions is estimated at 12,961 TPY VOC. This is an increase of 5,069 TPY from UBEI2017 (+1411 TPY from Oil production facilities and +3658 TPY from Gas production facilities).

6 Capture Effectiveness of Controlled Tanks

6.1 Purpose

This section outlines the method used to account for emissions from controlled storage tanks that fail to make it to their intended control devices (e.g. venting to the atmosphere through pressure relief devices) and incorporate these emissions into the UBEI2017-Update.

6.2 Background

The UBEI2017 is made up of two main components: (1) Operator Workbooks where operators provide prescribed data elements and emission estimates, and (2) Gap-Filling for emissions sources not covered in the Operator Workbooks. The emission estimates in the Operator Workbooks include emissions from storage tanks at production facilities. Tank emissions are estimated with software or Flash Gas-Oil Ratio (FGOR) derived from flash gas liberation of pressurized liquid samples in the lab. Either estimating approach assumes equipment is functioning as intended. There are 7,525 production facilities in the UBEI2017. Of those, 1,266 production facilities are reported as having controlled tank emissions where Operators reduce the estimated tank emissions by 95-98%, mostly through routing tank emissions to enclosed combustion control devices.

EPA and UDAQ have regularly observed instances of storage tank emissions not making it to their intended control devices. Studies and inspection observations conducted in the Uinta Basin have identified a similar prevalence as summarized in Table 4. This is not unique to the Uinta Basin and a description of national findings, along with detailed design and operation and maintenance

considerations on the tank vapor capture system, were provided in an EPA compliance alert² issued in September 2015.

Table 4 Uinta Basin Studies and Observations on Controlled Tank Emissions

Study Inspection	% Sites w/ Controlled Tanks Emitting	Year	# Sites Surveyed
STEPP - Storage Tank Emissions Pilot Project ³	39%	2016	454
Aerial & Ground IR Survey ⁴	31%	2018	517
EPA Inspections	47%	2018	88

6.3 Method

1. From Uinta Basin specific studies and field observations in Table 4, and to be conservative, assume that 30% of the production facilities with controlled tanks experience emissions not making it to their intended control device.
2. From the UBEI2017-Update, select production facilities with controlled tanks in Uintah & Duchesne counties.
3. From these data 30% were randomly selected to be malfunctioning.
4. For these selected facilities their controlled emissions were replaced with uncontrolled emissions backing out their reported control percent.
5. Step 2 and 3 were repeated 10,000 times as part of a Monte Carlo simulation.
6. The mean value from the 10,000 runs reflect the tank emissions not making it to the control device.
7. From this resultant value, the controlled VOC value was subtracted so as to only have only those extra emissions that would have come from a malfunctioning system.

6.4 Results

Following updates to total VOC emissions from oil and condensate tanks according to the Uinta Basin Composition Study profiles, a 10,000 run Monte Carlo simulation was repeated. We found that updated mean VOC emissions that would be generated from storage tank emissions not making it to their intended control device would be 14,982 TPY VOCs (Figure 5). The majority of these VOC emissions – 14,077 TPY – are associated with oil tanks, and the remaining 905 TPY are associated with condensate tanks. Monte Carlo analysis for UBEI2017-Update yielded a much greater VOC TPY than the initial analysis for UBEI2017 due to operator workbook updates described in the Preparation of UBEI2017 Data for Analysis section in this white paper for V1.85. Particularly influencing this analysis was the addition of 174 oil wells producing from 106 production facilities, 105 of which report controls on the tanks. The 105 added oil production facilities with controlled tanks account for ~8% of all production facilities with

² “EPA Observes Emissions from Controlled Storage Vessels at Onshore Oil and Natural Gas Production Facilities” September 2015. <https://www.epa.gov/sites/production/files/2015-09/documents/oilgascompliancealert.pdf>

³ “STORAGE TANK EMISSIONS PILOT PROJECT (STEPP): FUGITIVE ORGANIC COMPOUND EMISSIONS FROM LIQUID STORAGE TANKS IN THE UINTA BASIN” Final Report to The Utah State Legislature, July 17, 2017. USU, TriCounty Health Dept, UDAQ. <https://documents.deq.utah.gov/air-quality/planning/technical-analysis/research/oil-and-gas/DAQ-2017-014389.pdf>

⁴ “Hydrocarbon Emission Detection Survey of Uinta Basin Oil and Gas Wells”. November 2018. Bingham Research Center, Utah State University. <https://usu.box.com/s/y3njm7wulu2gr4ff8itdsismmud2rxf8>

controlled tanks, but ~73% of VOCs of uncontrolled emissions from all controlled tanks. When controlled tank facilities were randomly selected and controls backed out, the disproportionate share of emissions from the added wellpads significantly impacted the results.

The UBEI2017-Update total capture effectiveness of controlled tanks VOC emissions is estimated at 14,982 TPY VOC. This is an increase of 1,036 TPY from UBEI2017.

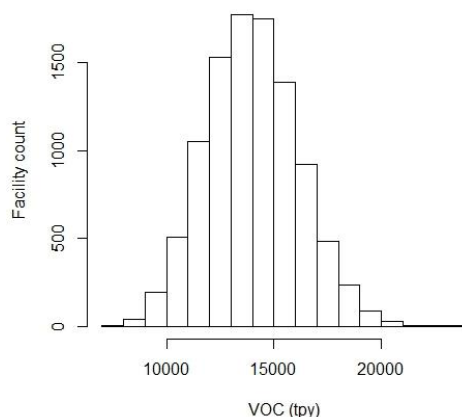


Figure 5 Histogram of the 10,000 run Monte Carlo simulation based on UBEI2017-Update

7 Gas Well Liquid Unloading

7.1 Purpose

This section outlines the method used to account for well venting for liquids unloadings to incorporate in the UBEI2017 and the changes estimated from findings in the Uinta Basin Composition Study⁵.

7.2 Background

The Uinta Basin Oil & Gas Emission Inventory (UBEI) is made up of two main components: (1) Operator Workbooks where operators provide prescribed data elements and emission estimates, and (2) Gap-Filling for emissions sources not covered in the Operator Workbooks. Operators annually report to EPA's Greenhouse Gas Reporting Program, subpart W (Petroleum and Natural Gas Systems), methane emissions and activity counts for well liquids unloading.

In new gas wells, there is generally sufficient reservoir pressure to facilitate the flow of water and hydrocarbon liquids to the surface along with produced gas. In mature gas wells, the accumulation of liquids in the well can occur when the bottom well pressure approaches reservoir shut-in pressure. This accumulation of liquids can impede and sometimes halt gas production. When the accumulation of liquid results in the slowing or cessation of gas production (i.e., liquids loading), removal of fluids (i.e., liquids unloading) is required in order to maintain production. Emissions to the atmosphere during liquids unloading events are a potentially significant source of VOC and methane emissions.

⁵ Uinta Basin Composition Study Comprehensive Final Report, Utah Division of Air Quality. March 31, 2020 <https://documents.deq.utah.gov/air-quality/planning/technical-analysis/DAQ-2020-004826.pdf>

Most gas production facilities will have liquid loading occur at some point during the productive life of the well. When this occurs, common courses of action to improve gas flow include⁶:

- Shutting in the well to allow bottom hole pressure to increase, then venting the well to the atmosphere (well blowdown, or “blowing down the well”),
- Swabbing the well to remove accumulated fluids,
- Installing a plunger lift,
- Installing velocity tubing, and
- Installing an artificial lift system.

7.3 Method

1. From the EPA Greenhouse Gas Reporting Program, subpart W reporting from operators in the Uinta Basin, obtain the activity levels and resultant methane emissions (reported in metric tons). For Reporting Year 2017, operators in the Uinta Basin reported the following for well liquids unloading:

Table 5 2017 Uinta Basin Well Liquid Unloading

GHGRP-W RY2017 UINTA BASIN (AAPG 575)

	# Wells Vented	Cumul. # of Unloading Events	Volume Gas Vented (scf)	CH4 Emissions (MT)
County				
Carbon	180	798	1,120,359	19
Duchesne	43	321	4,509,891	3
Uintah	1,081	114,202	223,175,171	3,845
TOTAL	1,304	115,321	228,805,421	3,867

Plunger Lift				
Yes	828	112,953	193,645,025	3,362
No	476	2,368	35,160,396	505
TOTAL	1,304	115,321	228,805,421	3,867

Operator				
Anadarko	388	1,191	20,348,151	327
Enervest	180	798	1,120,359	19
EOG	157	464	989,853	16
EP Energy	52	345	4,765,981	4
QEP	387	111,859	199,623,053	3,467
XTO	140	664	1,958,024	34
TOTAL	1,304	115,321	228,805,421	3,867

2. Obtain speciation data for ‘flash gas analysis for condensate (at gas wells)’ to use as a surrogate ratio of methane-to-VOC weight percent (Wt.%) for the unloading of pressurized liquids from gas wells through an atmospheric storage tank.

⁶ “Oil and Natural Gas Sector Liquids Unloading Processes”, April 2014
<https://www.regulations.gov/document?D=EPA-HQ-OAR-2010-0505-5032>

- a. For UBEI2017:

From the 2014 UBEI, calculate the weighted average (based on # of facilities) of speciated gas streams provided by operators. From the weighted average of 'flash gas analysis for condensate', the weight percent of methane (CH₄) is 0.3180 and of VOCs is 0.4958.

$$\frac{VOC \text{ Wt. \% (0.4958)}}{CH_4 \text{ Wt. \% (0.3180)} \times \frac{(0.907185) \text{ MT}}{\text{ton}}} = 1.7184 \frac{VOC \text{ ton}}{CH_4 \text{ MT}}$$

- b. For UBEI2017-Update based on UBCS findings:

From the UBCS, use the average speciated "Flash Gas: Gas Wells" gas stream derived from 17 gas production facilities where pressurized liquid samples from the separator were collected and analyzed and those results input to ProMax to model speciated tank flash emissions. The UBCS speciation profiles are shown in Table 1.

The weight fraction of methane (CH₄) is 0.4602 and of VOCs is 0.3565.

$$\frac{VOC \text{ Wt. \% (0.3565)}}{CH_4 \text{ Wt. \% (0.4602)} \times \frac{(0.907185) \text{ MT}}{\text{ton}}} = 0.8539 \frac{VOC \text{ ton}}{CH_4 \text{ MT}}$$

3. Calculate VOC emissions from well liquids unloading in 2017⁷.

- a. For UBEI2107-Update based on UBCS findings:

$$3,867 \text{ MT } CH_4 \times 0.8539 \frac{VOC \text{ ton}}{CH_4 \text{ MT}} = 3,302 \text{ ton } VOC$$

7.4 Results

The UBEI2017-Update total well liquid unloading VOC emissions is estimated at 3,302 TPY VOC. This is a decrease of 3,343 TPY from UBEI2017.

8 Blowdowns and Pigging

8.1 Purpose

This section outlines the method used to account for emissions from blowdown venting to incorporate in UBEI2017 and the changes estimated from findings in the Uinta Basin Composition Study⁸.

⁷Prior to emissions adjustments according to UBCS, VOC emissions from well liquid unloadings were as follows:

$$3,867 \text{ MT } CH_4 \times 1.7186 \frac{VOC \text{ ton}}{CH_4 \text{ MT}} = 6,645 \text{ ton } VOC$$

⁸ Uinta Basin Composition Study Comprehensive Final Report, Utah Division of Air Quality. March 31, 2020
<https://documents.deq.utah.gov/air-quality/planning/technical-analysis/DAQ-2020-004826.pdf>

8.2 Background

The Uinta Basin Oil & Gas Emission Inventory (UBEI) is made up of two main components: (1) Operator Workbooks where operators provide prescribed data elements and emission estimates, and (2) Gap-Filling for emissions sources not covered in the Operator Workbooks. Operators annually report to EPA's Greenhouse Gas Reporting Program, subpart W (Petroleum and Natural Gas Systems), methane emissions and activity counts for blowdown vent stacks.

For onshore petroleum and natural gas gathering and boosting activities, blowdown vent stacks⁹ equipment or event types are grouped into the following seven categories: Facility piping (i.e., piping within the facility boundary other than physical volumes associated with distribution pipelines), pipeline venting (i.e., physical volumes associated with distribution pipelines vented within the facility boundary), compressors, scrubbers/strainers, pig launchers and receivers, emergency shutdowns (this category includes emergency shutdown blowdown emissions regardless of equipment type), and all other equipment with a physical volume greater than or equal to 50 cubic feet. If a blowdown event resulted in emissions from multiple equipment types and the emissions cannot be apportioned to the different equipment types, then the blowdown event is categorized as the equipment type that represented the largest portion of the emissions for the blowdown event.

8.3 Method

1. From the EPA Greenhouse Gas Reporting Program, subpart W reporting from operators in the Uinta Basin, obtain the activity levels and resultant methane emissions (reported in metric tons). For Reporting Year 2017, operators in the Uinta Basin reported the following for the seven categories of blowdown vent activities:

⁹ 40 CFR Part 98, §98.233(i)

Table 6 2017 Uinta Basin Blowdowns**GHGRP-W RY2017 UINTA BASIN (AAPG 575) - Blowdowns**

Operator	# Blowdown Events By-Type							TOTAL
	Compressors	Emergency shutdowns	Facility piping	Pig launchers & receivers	Pipeline venting	Scrubbers/strainers	Other equip. w/ Volume ≥ 50 ft3	
Anadarko	2,016	35	11	484	144	72	148	2,910
Andeavor	822	22	6		10	2		862
Crescent Point				6,968				6,968
EnerVest	836	-	-	572	2	-	-	1,410
Kinder Morgan	258	1					5	264
Newfield					108			108
XTO	532							532
TOTAL	4,464	58	17	8,024	264	74	153	13,054

Operator	CH4 Emissions (MT)							TOTAL
	Compressors	Emergency shutdowns	Facility piping	Pig launchers & receivers	Pipeline venting	Scrubbers/strainers	Other equip. w/ Volume ≥ 50 ft3	
Anadarko	59	17	0	2	347	2	4	431
Andeavor	205	56	0		0	0		261
Crescent Point				13				13
EnerVest	8	-	-	2	3	-	-	13
Kinder Morgan	6	67					337	410
Newfield					143			143
XTO	6							6
TOTAL	284	140	0	17	493	2	341	1,277

There is not a sub-basin (i.e. county) breakdown of this data.

2. Obtain speciation data for a ratio of methane-to-VOC weight percent (Wt.%) for blowdowns of equipment and piping.

- a. For UBEI2017-Update based on UBCS findings:

From the UBCS, use the average speciated “Raw Gas: Oil Wells” gas stream derived from 50 oil production facilities where gas samples were collected off the separators and analyzed and the “Raw Gas: Gas Wells” gas stream derived from 17 gas production facilities where gas samples were collected off the separators and analyzed. The UBCS speciation profiles are shown in Table 1.

For blowdowns in oil production regions use the weighted average of “Raw Gas: Oil Wells”, the weight fraction of methane (CH₄) is 0.5236 and of VOCs is 0.3254.

$$\frac{0.3254 \times \frac{VOC \text{ ton}}{\text{whole gas ton}}}{0.5236 \times \frac{CH_4 \text{ ton}}{\text{whole gas ton}} \times \frac{(0.907185) \text{ MT}}{\text{ton}}} = 0.6850 \frac{VOC \text{ ton}}{CH_4 \text{ MT}}$$

For blowdowns in gas production regions use the weighted average of “Raw Gas: Gas Wells”, the weight fraction of methane (CH₄) is 0.7308 and of VOCs is 0.1480.

$$\frac{0.1480 \times \frac{VOC \text{ ton}}{\text{whole gas ton}}}{0.7308 \times \frac{CH_4 \text{ ton}}{\text{whole gas ton}} \times \frac{(0.907185) MT}{\text{ton}}} = 0.2232 \frac{VOC \text{ ton}}{CH_4 MT}$$

Allocate the GHGRP-W blowdown data to either oil producing regions or gas producing regions as follows:

Table 7 Blowdown allocation

Operator	CH ₄ Emissions (MT)							TOTAL
	Compressors	Emergency shutdowns	Facility piping	Pig launchers & receivers	Pipeline venting	Scrubbers/strainers	Other equip. w/ volume ≥ 50 ft ³	
Anadarko	59	17	0	2	347	2	4	431
Andeavor	205	56	0		0	0		261
Crescent Point				13				13
EnerVest	8	-	-	2	3	-	-	13
Kinder Morgan	6	67					337	410
Newfield					143			143
XTO	6							6
TOTAL CH₄	284	140	0	17	493	2	341	1,277
Raw Gas - Oil	6	67	-	13	143	-	337	566
Raw Gas - Gas	278	73	0	4	350	2	4	711
Raw Gas - Oil	0.6850	VOC ton/CH ₄ MT						
Raw Gas - Gas	0.2232	VOC ton/CH ₄ MT						
TOTAL VOC (ton)	66	62	0	10	176	0	232	546

3. Calculate VOC emissions from blowdowns in 2017.
 - a. For UBEI2017-Update based on UBCS findings:
 - i. In oil regions:

$$566 \text{ MT CH}_4 \times 0.6850 \frac{VOC \text{ ton}}{CH_4 \text{ MT}} = 388 \text{ ton VOC}$$

- ii. In gas regions:

$$711 \text{ MT CH}_4 \times 0.2232 \frac{VOC \text{ ton}}{CH_4 \text{ MT}} = 158 \text{ ton VOC}$$

Total for Uinta Basin: 388 + 158 = 546 Tons VOC

8.4 Results

The UBEI2017-Update total blowdowns and pigging VOC emissions is estimated at 546 TPY VOC. This is an increase of 177 TPY from UBEI2017.

9 Updated 2017 Uinta Basin Oil and Gas Emissions Inventory (UBEI2017-Update)

Results of the above analyses are reflected for the Uinta Basin Oil and Gas Emissions Inventory in the Table 8 below. Green cells indicate an increase in VOC emissions due to adjustments described in this white paper, and red boxes indicate a decrease in VOC emissions in that emissions source category.

Table 8 UBEI2017-Update Emissions summary - VOCs (tons/year) Duchesne + Uintah counties

Uintah & Duchesne Counties Description 2017 Utah O&G EI (Operator Workbooks)	VOCs (tons/year)		
	UBEI2017		UBEI2017-Update
	V1.81	V1.85	V1.86
Dehydrators	4,517	4,517	4,517
Dehydrator Combustors	0	0	0
Fugitives	17,383	17,751	18,248
Pneumatic Controllers	3,928	3,881	5,474
Pneumatic Pumps	8,761	8,734	11,590
RICE & Engines	1,732	1,710	1,710
Separators & Heaters	153	147	147
Tanks (Oil and Condensate)	7,195	7,892	12,961
Tanks (Water)	1,143	1,144	1,144
Tank Combustors	1	1	1
Truck Loading	1,122	1,175	1,175
Well Completions (Drilling)	526	526	526
Centrifuges	10	10	10
Solid Waste Disposal	288	288	288
Produced Water	7,820	7,820	76,957 ¹⁰
SUBTOTAL Emissions Reported in Operator Workbooks	54,579	55,596	134,747
Capture Effectiveness Adjustment for Tank Emissions			
Control Effectiveness Adjustment (Water Tanks)	0	0	0
Control Effectiveness Adjustment (Condensate Tanks)	432	432	905
Control Effectiveness Adjustment (Oil Tanks)	3,077	13,514	14,077
UDOGM Incident Reports			
Midstream Vent (maint, startup/shutdown, malfunction)	667	667	667
Pipeline Leaks	166	166	166
Greenhouse Gas Emissions Reporting Program Additions			
Gas Well Venting (Blowdowns)	6,645	6,645	3,302
Pipeline Blowdowns and Pigging	369	369	546
EPA National Oil and Gas Tool			
Associated Gas Venting	446	446	446
CBM Dewatering Pumps	0	0	0
CBM Well Venting (Blowdowns)	0	0	0
Mud Degassing	545	545	545
Point Source Inventory			
Point Sources (Reported in SLEIS)	250	250	250
Combined Total (Duchesne + Uintah) VOC Emissions	67,176	78,630	155,651

¹⁰ "PRODUCED WATER DISPOSAL FACILITY EMISSION FACTORS & THEIR IMPACT ON THE 2017 OIL AND GAS EMISSIONS INVENTORY" White Paper, UDAQ, 2020.

10 Conclusions & Next Steps

Findings from research and requested information have provided an opportunity to update the UBEI2017 for a more accurate inventory for air quality management purposes. It is the intention of the Air Agencies to use UBEI2017-Update as the inventory for future policy analysis and rulemaking for oil and gas sources under their jurisdiction in the Uinta Basin. It would also be utilized in context of the potential Implementation Plans (IP) that may need to be prepared for the Uinta Basin ozone nonattainment area. This will also aid in demonstrating the regulatory requirements of a 15% reduction of VOC emissions, attainment modeling, and RACT/RACM analysis. It is in the interest of all stakeholders that regulatory decisions are based upon the most accurate available information for identifying the most pragmatic, cost-effective and ozone-reducing-effective strategies to achieve attainment of the ozone standard.

Though planning and preparing for a possible moderate SIP needs to begin as soon as possible, the EPA, UDAQ, and Ute Indian Tribe will continue to work to improve the emission inventory for the Uinta Basin. The agencies are also interested in improvements to the following areas of the Uinta Basin emission inventory:

10.1 Existing Emission Source Categories for Improvement

- Associated gas venting and flaring
 - Distinguishing between flared versus vented associated gas
 - Emissions from pit/emergency/overflow tanks
- Combustion by-products
 - Equipment burning field gas: tank heaters, separators, engines, combustors, etc.
 - Pumpjack engines
- Produced water disposal facilities

10.2 Possible Missing Emission Categories

- Methanol emissions: upstream & midstream sources
- Super-emitters from malfunctions or abnormal process conditions
- Emissions from abandoned wells and shut-in wells